Best Practices for Urban Densification: A decision-making support process using microclimate analysis methods and parametric models for optimizing urban climate

Best Practices for Urban Densification

A decision-making support process using microclimate analysis methods and parametric models for optimizing urban climate comfort

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Abstract. *This paper presents an approach for microclimate aware densification of urban areas by creating best practices for an in situ application for block-size urban developments.*
The discussed procedure generates and evaluates urban block types according to microclimate criteria by integrating climate and comfort parameters in the design process of existing urban areas. It supports urban designers by generating design strategies that aim for climate, comfort and spatial as well as for urban design qualities.
To achieve this, a multi-step method with different analysis and research processes has been set up. At the end, a parametric envelope tool was created for a local case study area by incorporating pre-defined design strategies built on previous investigations as urban design strategies. It is expected that this envelope tool can be transferred to similar urban development activities and guide microclimatic versus densification trade-offs. The presented approach can be applied from street canyon to block size urban situations.
Keywords. *Urban design; parametric modelling; analysis tools; strategic densification; microclimate evaluation; decision-support tools; decision-making process.*

INTRODUCTION

Since the world is facing the striking and critical process of climate change, the uncontrolled population growth and the increase in urban densification, we have been forced to re-evaluate and rethink the traditional methods for architecture and urban planning. It is indispensable to implement transdisciplinary strategies for the planning process of urban settlements towards sustainable environments.

In some of the recent studies on sustainable city models, especially in the compact city, increasing the urban density inside the existing urban areas is a crucial step when it comes to sustainable development (Jabareen, 2006). However, it can be a questionable policy where inner city areas are already very dense, therefore, higher density is not an absolute concept, but a relative one (Jenks and Burgess, 2000). The creation of sustainable urban areas from further densification will be limited under conditions where densities are already high. In order to address these issues, it is important to focus on specific areas under development, where there are no major densities but where urban containment can still be achieved. In this way, strategic densification processes can be undertaken according to particular urban contexts.

Densification is also linked to the fact that the world population is increasing independently of what we do to restrain it, therefore smart strategies for future densification of cities are crucial for the construction of sustainable built environments. A failure to address this issue can lead to ever-expanding cities, which consume more natural areas and grow until urban systems, like public transport, become unsustainable. One possible direction towards achieving densification without promoting urban sprawl is by reusing urban spaces inside the city (Martin, 2008). This can also prevent the deterioration of urban areas and the consumption of natural environments.

In this paper, we will introduce a first approach, which aimed to create a method to integrate microclimate and comfort parameters in the design process in order to obtain urban design strategies for the densification of existing urban blocks.

This method was developed and implemented under the frame of the National Research Program NRP 65 'Sustainable Urban Patterns (SUPat)' project [1], which aims to integrate qualitative and quantitative design and research activities through collaborative urban planning processes and visualization-simulation tools. Within this project, different regional future scenarios for the case study Limmattal region in Switzerland were evaluated and explored in order to propose sustainable urban patterns for future developments.

URBAN DESIGN STRATEGIES

Preceding to this present work, a review on urban design strategies was conducted in order to support the creation of the method. This study was focused on the different urban design strategies primarily according to Christiaansen (2005), Ford (2000), Hebbert (2005) and Martin (2008), among others.

The results of this study were divided into four main sections; urban morphology, quality of urban space, urban layouts and envelope concept. Within these sections, different concepts were analysed, like morphological elements, morphological transformation, connected street patterns, urban block, visual quality of space, urban traffic, density and concentration, urban layouts, etc.

As a basis process the envelope theory of Christiaansen (2005) was used on the final steps of the presented method. The result of this process was used as a set of possible development scenarios for the densification of the selected case study.

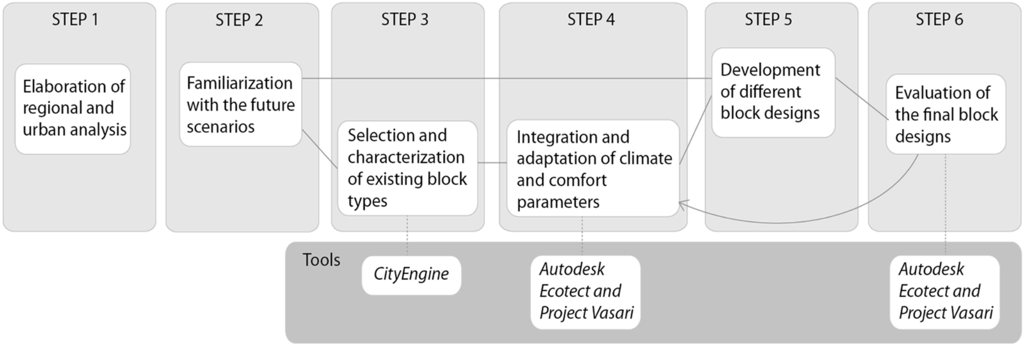
METHOD

The main goal of the presented method was to create and evaluate urban design strategies, using microclimate and urban analysis methods, which are then available in the form of a decision support tool for the densification of existing urban blocks following future city development scenarios.

The method was divided into six different steps considering environmental and urban analysis processes (Figure 1). The first step consisted on the regional and urban analysis of the case study area in order to get some insight into how the local area is shape according to network systems, natural and built areas, and land use. The following step was the review and analysis of the future development strategies or scenarios that the city intends for the selected urban area. With this, the next step was the identification and characterization of the existing urban typologies at a block scale. At this point, we obtained the necessary information, concerning the current situation, in order to proceed on to the transformation of the urban-block envelope as the successive step. Eventually, a final urban envelope was created for a local case study area, as a set of possible development areas for the densification of existing blocks. From this final envelope, different block designs were generated according to future city scenarios. With these new variants, the following step was to simulate and evaluate the environmental effects by using environmental analysis tools.

The microclimate analysis and simulation processes (shadow range, visual impact and wind tun-

Figure 1
Method for the analysis and creation of best practices for urban blocks. This approach evaluates urban block types according to microclimate criteria and integrates climate and conform parameters in the design process of existing urban areas. The method is divided into 6 steps, where a code-based tool visualise the documented data and environmental analysis tools support the different sets of microclimate and comfort analysis.



nels) were performed in Autodesk Ecotect and Autodesk Vasari to deduce microclimate intensities. The designer did the rest of the analysis and procedures, including the final block variants. Concerning the information provided to and from the overall method, the input data came from the existing situation of the urban area and the desired requirements of future scenarios. On the other hand, the outcome or the results were the final variants or the final urban block design. Due to the construction of the method as a set of different steps, every step had its own input information and results, therefore the outcome of a previous step was the input for the following one.

IMPLEMENTATION

One of the first steps of the aforementioned SUPat project was to develop future development scenarios (Wissen Hayek et. al, 2011) for the *Limmattal* region in Switzerland as a basis for the modelling of possible sustainable urban patterns. These shell scenarios were established according to a number of specific parameters and projected for the years 2030/2050 [1]. The output scenarios took shape as four different regional future outlooks appointed as: Pure Dynamic, Character City, Smart City and Charming Valley. With Altstetten Zurich as case study, these four future scenarios were used as a starting point for the implementation process of the presented method.

Step 1

The first step consisted on the elaboration of regional and urban analysis of the local case study area and its context. In this way, an understanding of the case study conditions and its surroundings was achieve by the analysis and documentation of the different existing urban systems (Network system, natural and green areas, zone plan, etc.). The future strategies for the area were also extracted from the official city planning documentation, in order to identify potential sectors, desired pathways of development, densification processes, urban design guidelines, and the essential character for the overall development.

In general, this part was important in order to study and select possible urban areas under development to be able to classify specific locations for implementing strategic densification processes. Therefore, this part helped us to recognize and locate the urban areas that are currently under development or strategically disposed for future interventions. In this way, we selected the potential sectors inside Altstetten in order to apply strategically densification processes according to microclimate parameters. These areas were mainly in the north and eastern part of the urban settlement like show in Figure 2.

Step 2

As mentioned before, for the implementation part we used the four future shell scenarios developed by the SUPat project for the *Limmattal* region and

Figure 2
Strategy maps from the information of the Zürich city plan.

the urban area of Zurich Altstetten. For this step, a conceptual analysis of the future shell scenarios was elaborated in the form of simple diagrams. According to the information given from the project, the diagrams were organized in three main topics; (i) development of centres, (ii) distribution of green areas and (iii) density and distribution of residential areas. Individually, these diagrams represent the general desired ideas, which characterize the development of the area for each future scenario (Figure 3). This conceptual analysis was important in order to understand the possible future city developments and the overall characteristics, pathways and strategies. In this way, the different scenarios were assessed in order to support decision–making processes for the development of this urban area.

From the information provided by the SUPat project regarding these scenarios, the conceptual maps were created with the purpose of visualizing the data that characterized each of these setups. Therefore, we obtained visual information about the characteristics of each scenario. For instance, we could identify the difference of the strong network of green spaces in the Charming Valley compare with the other scenarios. This results were the base data for the step 5 when creating the design variants of each scenario.

Step 3

The third step was the selection and characterization of existing block types. Starting from the current situation and after analysing the different urban forms, a matrix with the existing different block types was created and divided into groups according to the zone plans and the building typologies (Figure 4). This process was executed by, first identifying the different block types for each of the different land-use areas and then, documenting these block types according to the urban layouts (Lot division, building distribution and trees distribution). We could identify that each block type has its own characterization according to the disposition of the urban elements. For example, Type 1 of the residential | W3 (three stores buildings) was defined as urban blocks of single-house lots with internal small roads leading into internal lots.

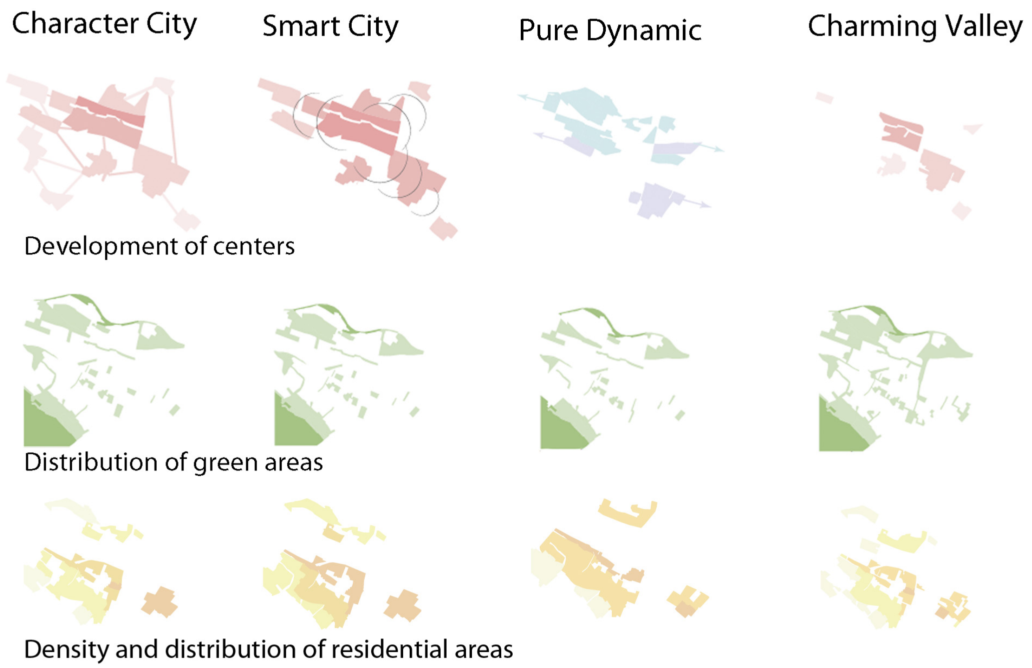


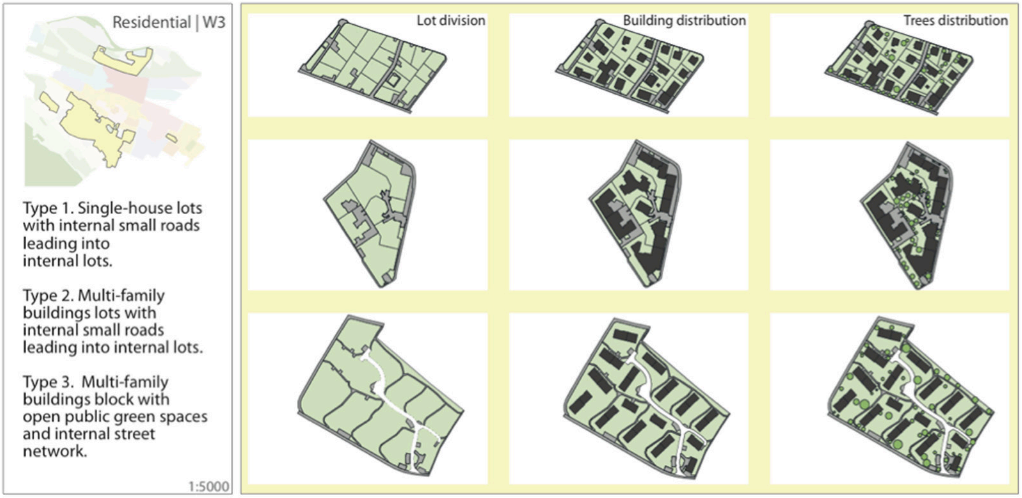
Figure 3
Conceptual diagrams of the four future city scenarios from the SUPat project.

With this information documented, each block type was further analysed in terms of design parameters and guidelines like, for example: public spaces, green areas, pedestrian pathways, building height, etc. This analysis provided some insights of how the existing urban blocks where created for the different land-uses, and under which design guidelines. In addition, these block types were visualized with a procedural rule-based method using Esri CityEngine [2]. This tool allowed documenting the design guidelines of each block type into rule-based data, which was applied to the same block types within the case study area and eventually we obtained a 3D visualization model for the whole urban area (Müller et al., 2006).

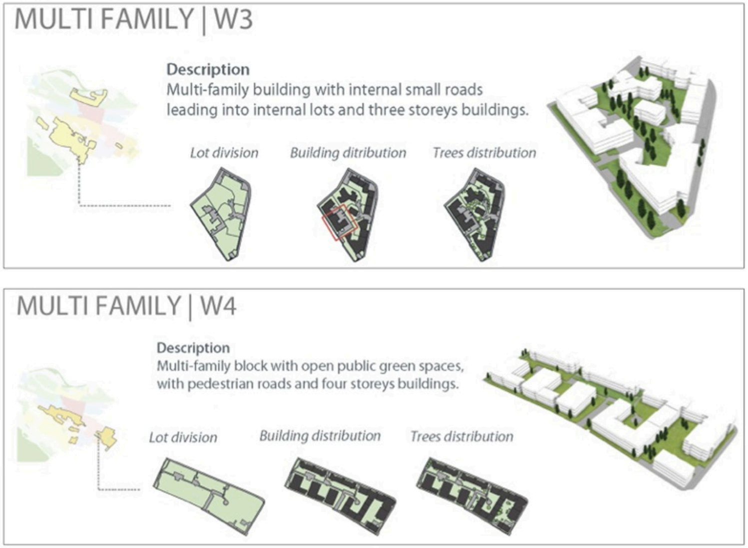
As a whole, this step was intentioned towards a better understanding of the existing situation of the urban blocks, in order to support future interventions and to recognize the capacity of theses urban areas to sustain densification processes. According to this, it was evident that the block types in the developing urban areas recognized in step 1 were less defined and more open to further development. Therefore, for the next steps we selected one of these urban blocks to experiment on densification processes of existing block-scale areas, taking into consideration microclimate conditions.

Step 4

The next step was the integration and adaptation of climate and comfort parameters to the urban envelope (Christiaanse, 2005), and its implementation into the existing block types described in the previous step. The envelope concept consists on covering a complete urban block with an envelope, which constitutes possible areas of intervention and, according to several urban analysis procedures the envelope is transformed until it reaches the ideal areas for future interventions. For the purpose of this research, this concept was adapted according



(i) Matrix



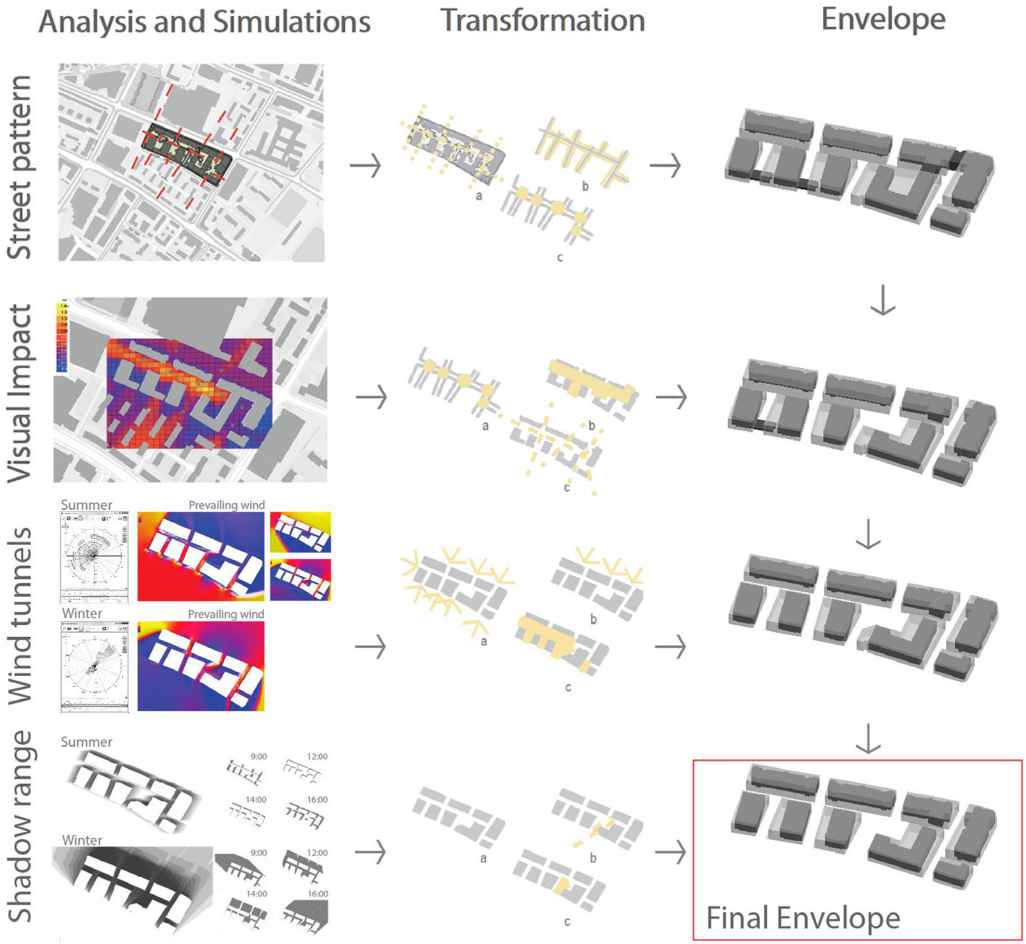
(ii) Description of design guidelines

Figure 4
(i) Example of the documented information of the different block types divided into lot, building distribution and trees distribution. (ii) Two examples of the documentation of the design guidelines of the different block types with a 3D model created in Esri CityEngine.

to climate and comfort parameters and then implemented in an existing urban block (residential focus area) selected in the previous step.

This process was divided into several sub-steps each dealing with, either street patterns, visual impact, shadow range or wind tunnels. Using rapid environmental analysis tools (Autodesk Ecotect and Autodesk Vasari), each step contributed to the con-

Figure 5
Steps of the envelope transformation



struction of a new envelope as a starting point for further densification of existing urban blocks (Figure 5). The new envelope was used as a container to regulate the parameters and the design guidelines obtained by the different analyses and simulations.

Each of these steps initiated with a specific analysis or simulation, going through a transformation and finally obtaining the new form of the envelope. The envelope started as a shape, which covered the whole block and was determine according to the building normative of the area and the physical boundaries of the block. The first procedure was the street patter analysis, which provided the first shape of the envelope. After this transformation, a visual impact analysis was performed towards finding the areas of the block that were more visible for pedestrians in order to extract them from the envelope. The next transformation was based on the wind tunnels simulation, allowing bigger canyons in the direction of the prevalent wind in summer and smaller

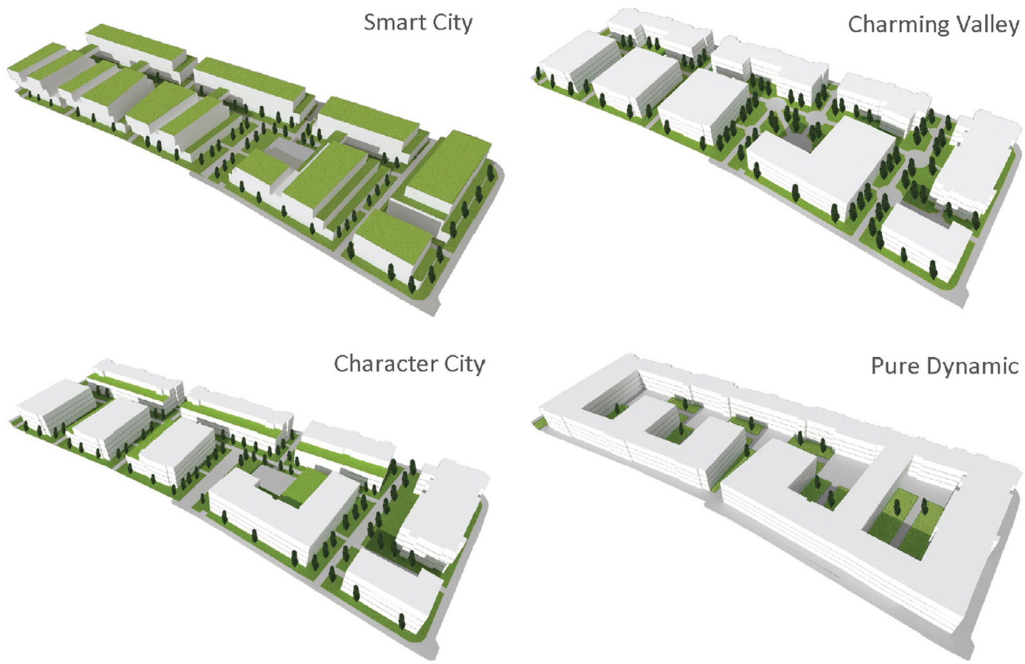


Figure 6
Block design variants for each future scenario.

where the prevalent wind flows in winter. Finally the shadow range analysis provided the final changes of the envelope by leading the winter sunlight remain in the open spaces for as long as it is possible. With the basic urban and microclimate criteria, the final envelope was now shaped and ready to be expose to further densification processes.

Step 5

In order to develop different block designs for the four future scenarios mentioned before, the resulting envelope from the previous process was used as a starting point. A variant for each future scenario was elaborated by the designer according to the characteristics defined in the SUPat project [2] and as analysed in step 2. Therefore, a final block design was created for each of these scenarios as shown in Figure 6.

These four different variants had two main purposes. The fist purpose was to put into practice the adapted envelope process in order to evaluate its performance. The second purpose was to support the evaluation of the SUPat scenarios by providing visual information in a block scale for the future discussion of the different scenarios.

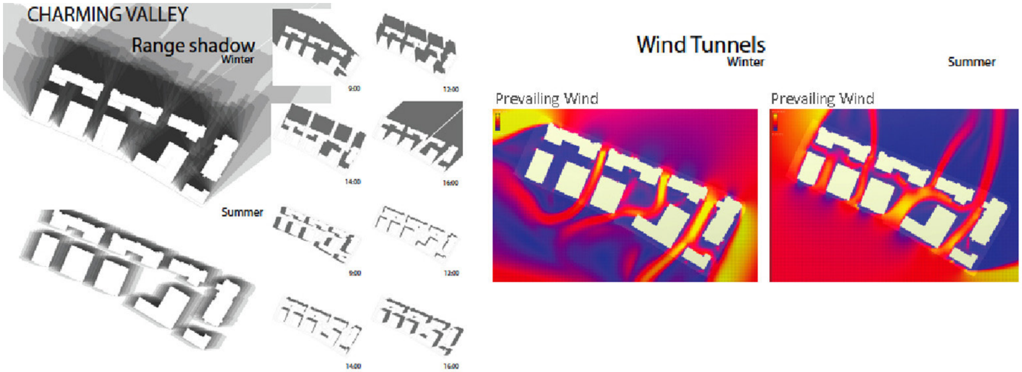
Due to the particularly extreme characteristics of the Pure Dynamic scenario given by the SUPat project, the block design broke the boundaries of the envelope making this the only variant without the predefine shape from the envelope.

Concerning the other three variants, the form of the final envelope worked as a containment or regulation for the new development in the existing block. As stated before, the different in the designs depended on the characteristics that shaped each scenario.

Step 6

The microclimate performance of the final block variants was then evaluated using the same envi-

Figure 7
Evaluation of the block designs (Charming Valley).



ronmental analysis tools that were used initially to adapt the envelope. Hence, the variants were subjected to evaluation in order to examine the performance of the final envelope and to study ideal design strategies towards the exploration of best practice scenarios according to microclimate parameters (Figure 7).

After the evaluation, it was clear that the Pure Dynamic scenario was not the best-practice block design towards enhancing the use of microclimate parameters to pursue sustainable urban patterns. This was evident since the characteristics of the scenario were not compatible with the parameters of transformation of the envelope.

On the other hand, the evaluation of the other three scenarios corresponded with the expected results. However, a further and more detail evaluation should be based on other variables (e.g. social, economic and cultural) different from environmental criteria according to microclimate conditions. This consideration was established on the fact that the evaluation results of these variants were highly similar, therefore, other type of analysis should be consider in order to obtain more reliable results. Regarding the envelope transformation, this similar outcomes show that the envelope process was successful towards achieving design regulation parameters for future developments and only extremely different city scenarios, like the Pure Dynamic, can disrupt this envelope.

CONCLUSION

The method allowed us to evaluate different design strategies, based on microclimate and comfort parameters, for the densification of future cities scenarios according to a specific location. Also, this approach led to the creation of a design-based method for architects and urban designers to support the creation of microclimate-friendly urban patterns for the further development and retrofitting of existing blocks.

It is clear that the parameters for the construction and evaluation of the urban envelope process can change depending on the location. Additionally, the microclimate situation changes with every new location, therefore the urban strategies can differ from the ones evaluated in this specific case study. Despite the fact that the actual results of the case study were highly case-specific, the overall method described here can be used in different situations, by adapting the parameters to the specific location. However, the processes used for the evaluation of the microclimate conditions need to become more precise therefore the environmental tools used so far will be revisit as these were to deduced microclimate intensities and may not provide reliable data.

As a next step, the overall research framework wishes to build on the knowledge acquired from the described method, and introduce the social aspect in the search for sustainable urban solutions of different contexts.

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